International Journal of Automotive Technology, Vol. 8, No. 6, pp. 675−685 (2007)

1229−9138/2007/037−02

EFFECTS OF VARIOUS VVA SYSTEMS ON THE ENGINE FUEL ECONOMY AND OPTIMIZATION OF A CVVT-VVL SI ENGINE USING 1D SIMULATION

H. B. LEE, H. KWON and K. MIN*

School of Mechanical and Aerospace Engineering, Seoul National University, Seoul 151-744, Korea

(Received 28 May 2007; Revised 29 October 2007)

ABSTRACT−A single cylinder SI engine with a VVA system is modeled by the coupling of a commercial 1D simulation package and an additional combustion model and validated by comparison with experimental data. A number of simulations are carried out to investigate the effects of five different VVA systems on the performance and fuel efficiency of the baseline engine. Finally, the simulation model is applied to an extensive computational study to map out the strategies to operate the engines with dual CVVT and dual CVVT–2 step VVL systems in a fuel-efficient manner.

KEY WORDS: Variable valve actuation, CVVT, VVL, Fuel economy, Optimization, 1D Simulation

1. INTRODUCTION

Due to stringent global regulations on emissions and demands for highly fuel-efficient vehicles triggered by increasing oil prices, automotive engineers were prompted to consider a new technology, variable valve actuation, which could upgrade contemporary SI engines without a radical change of classical paradigm. It is a promising technology that can substantially improve performance, fuel efficiency, and emissions of engines at a relatively low cost (Moro *et al.*, 2001; Fiorenze *et al.*, 2003). Due to several technical problems, however, a fully variable valve system, which can alter valve timing, lift, and duration freely and independently, is a few steps short of realization (Pierik and Burkhard, 2000; Himsel *et al*., 2004). Therefore, although they are not sufficient to provide the projected benefits, some relatively simple forms of VVA systems have recently been devised and introduced into production engines, bringing remarkable achievements in the manufacture of fuel-efficient and environment-friendly cars. All of these simple VVA systems, however, are different from each other not only in terms of mechanism and basic principles, but also in their effectiveness; therefore, the effects of various VVA systems on engine performance must be evaluated quantitatively and their strength and potential must be examined.

When a VVA system is applied to an SI engine, the number of control parameters (such as intake valve open /close (IVO/IVC), exhaust valve open/close (EVO/EVC), duration, lift and overlap) increases substantially. Considering all of these parameters, an optimization study of a VVA SI engine must face a drastic increase in the number of operating points and unfortunately, the entire region of operation of the test engine cannot be investigated experimentally. For example, when three independent control parameters are newly added and five levels are assigned to each parameter, this will give rise to 125 times more operating points than the baseline engine. This is literally an exponential increase of number of operating points, and a straightforward experimental method cannot be applied due to time and cost concerns.

In an optimization study of multi-control-parameter engines like CVVT, VVL, and CVVT-VVL, the efficiency of the study itself plays an important role and should be taken seriously. Since a straightforward experimental study obviously has a lot of limitations in this case, other tools, such as simulation or design of experiment (DOE), should be considered to assist the experimental study. Modeling the test engine and carrying out simulations give rise to a considerable reduction of the number of experiments (Rask and Sellnau, 2004). The design of the experiment can also be very helpful to maximize the amount of information we are retrieving from a small number of tests (Bozza *et al.*, 2002). Either one of these methods can be employed in the study of multi-control-parameter engines, and this is also true for the study of a CVVT-VVL SI engine to make optimization procedure more feasible and efficient.

**Corresponding author.* e-mail: kdmin@snu.ac.kr